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Assessing vulnerability and adaptation responses to rainfall-related landslides in China, a case study of Enshi Prefecture in Hubei Province

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Abstract

Based on the questionnaire inquiring for landslide disaster of Enshi Autonomous Prefecture in Hubei province, the biophysical, socio-economic, experience, and emergency preparedness and adaptation strategies to disasters characteristics are classified by using SPSS cluster analysis method. It aims to ascertain landslide prone areas in China and assess their vulnerability to flooding and landslide. The results of the cluster analysis of the survey data generated three clusters, high vulnerable-traditional farmers, medium vulnerable-large economical farmers and low vulnerable-commercial and less-farm. The local government should take some accurate and effective measures to protect people and their property from destroying from rainfall-related landslide.

Keywords: Landslide; Cluster Analysis; Enshi Prefecture; vulnerability; Landslide-prone areas

1. Introduction

With the increasing of world population, the gradual expansion of human activities, increasing levels of disturbance, frequent flooding due to unsustainable land use and extreme climate events has caused landslides, which have damaged not only property, but also claimed lives of many people across China [1]. So far, the landslides have occurred at almost all the mountainous areas, which have inhabited and engineering activities. It has happened as the highest frequency and the biggest loss of all types of geological disasters [2]. With a vast territory, complicated landform and diverse climate, China is one of the most serious geological disaster-prone areas in Asia and even of the world. The landslide and flooding disaster is the main type in China. Results have shown that up to 51% geological disasters belong to

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landslide and flooding in the investigating of 290 counties and cities in China [2]. The landslide disasters caused vast economic losses and casualties and also led to severe damage to society. It is estimated that the losses caused by disasters for landslides can up to 20 billion Yuan of each year in China [3]. Considering the impacts of climate change on the intensity of precipitation and global trade on the pattern of land use, landslides are expected to become an important problem in vulnerable areas in China. Government should take some measures to facilitate a systematic procedure for predicting, warning of, and possibly forestalling, flood-related landslide events, as well as in providing mitigation and rehabilitation measures to deal with them. In order to be able to provide measures to help vulnerable regions to adapt to and recover from landslide risks, we chose Enshi Autonomous Prefecture in Hubei province as a case study to carry out some measures to challenge the task of ascertaining landslide-prone areas in China and assess their vulnerability to flooding and landslide.

2. Materials and Methods

2.1 Study area

Enshi Tujia and Miao Autonomous Prefecture is located at the southwest part of Hubei Province (108°23'-110°38' E, 29°07'-31°24' W), with the land area of 2.4×10^3 km^2, total population of 3.95 million, of which 28 minorities such as Tujia, Miao and Dong accounts for 52.6% [4]. The research area has an average elevation of 1000 meters above sea level. It has the subtropical monsoon mountain climate. The gulch has well developed because of the influence of physiognomy, landform, precipitation, and geological structure [5].

Landslides and other geological disasters happened frequently in Enshi Autonomous Prefecture, where geological disaster is one of the most serious problems in Hubei province and even in China. According to statistics from the preliminary investigation in 2002, there are 1763 geological disaster places, with percent of 75.4% (1,329) disaster places belong to landside sites [6].

2.2 Selection of survey areas

This survey selected the high degree of national landslide-prone area to make questionnaire survey in the Mufu town, Tunbao township of Enshi in Hubei Province. In Mufu town, three villages (Mufu Neighborhood committee, Yingshang village and Mugong village) were selected in this study. In our research, 99 residents which affected by landslide disasters differently (strong, medium and weak) were investigated as the survey experiment. Mufu neighborhood committee locates in lower terrain and bottom of slope. It is less affected by landslide disasters and subjected to a lesser extent of soil erosion. Yingshang village locates at the middle of the slope; the average elevation is above 800 meters. This village was more serious affected by landslide, and subjected to larger soil erosion. Mugong village locates in the top of slope and the elevation is higher than 1000 meters. This place was affected by landslide disasters most obviously, and there are 1,509 families and 5,560 people. The families affected by disasters up to more than 300, accounting for 1/5.

2.3 Determine of Questionnaire Content

In order to evaluate the vulnerability of local landslide,

this research adopted the questionnaire method. We carried on the investigation and analyzed into many aspects about the local farmers, which included the basic information, socio-economic, agricultural biological physics, local climatic conditions and government mechanisms and so on. Details of the research included, agricultural and biological physics (field elevation, slope, fertility, the soil

characteristics, soil layer thickness and so on), agricultural information (the crop planted, planting area, planting patterns and the reasons for such selection), basic information of local farmers (demographic situation, the level and main source of income), farmers disaster experiences and disasters before, during and after the measures taken by the government and the people and so on. We carried on the questionnaire survey in each investigation place by random selection. The investigation time is on March 8th until March 14th in 2009.

2.4 Data Analysis

With the completion field survey, data was analyzed to make quantification and statistic on all aspects of obtained information. The cluster analysis of questionnaire was carried by internationally statistical analysis software SPSS (Statistical Product and Service Solutions). Clustering method is a complete linkage cascade synthesis, the similarity measure is square Euclidean distance, and the clustering results are expressed by system tree diagram.

3. Results

3.1 Derivation of Cluster Groups using K-Means

Data was gathered from 99 residents in three villages (Mufu Neighborhood committee, Yingshang village and Mugong village) in Enshi Autonomus Prefecture, Hubei Province, China. The respondents were clustered based on years of residing in a community, ecology code, no. of parcels, total farm size, dominant farm slope, soil fertility status, soil texture, household size, age, education, income, available government help and so on. From the analysis, the residences are grouped into three clusters: Cluster 1, Cluster 2 and Cluster 3.

The three cluster groups generating from SPSS using the clustering K-Means method are showed in Table I. The cluster set consists of the socio-economic, biological and physical characteristics. This set of cluster distributes an almost equal number of residents.

TABLE I. Distribution of Enshi Prefecture residents according to cluster group

Cluster	**CHARACTERISTIC SETS**	
Groups	Biophysical	Socio-Economic + Biophysical
1	42	69
2	17	22
3	40	8

Figure 1 shows the plotted cluster groups based on selected characteristics of residents in study area by using hierarchical clustering. The plotted dendrogram shows the distribution of respondents by three clusters that belong to the same cluster share common socio-economic, biological and physical characteristics. It selects the distance of 20 for cluster. When the distance is 20, the 99 residents were classified into three cluster groups. It consists of 69, 22, and 8 in cluster 1, cluster 2 and cluster 3.

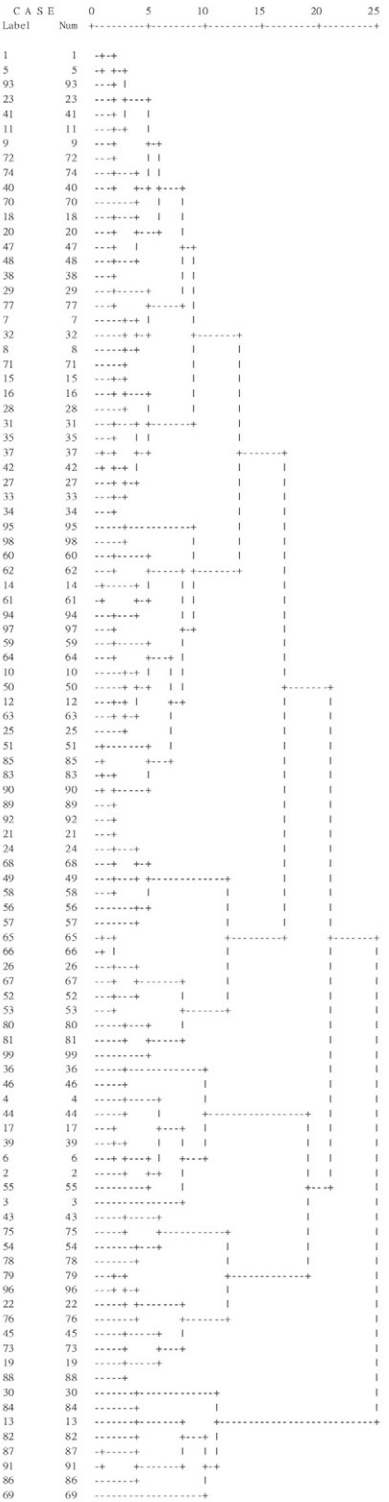

Figure 1. Dendrogram using hierarchal clustering

3.2 Cluster Vulnerabilities of Samples by Cluster Groups

Figure 2 shows that the three cluster groups from the three villages. Cluster 1 group is mainly from Yingshang (52.2%) and 31.9% are from Mugong village. Cluster 2 group consists of 59.1% Yingshang village, and 22.7% of Mugong village, while the rest are Mufu neighborhood committee (18.2%) residents. Cluster 3 group has a few residents and 75% residents are from Yingshang sitio.

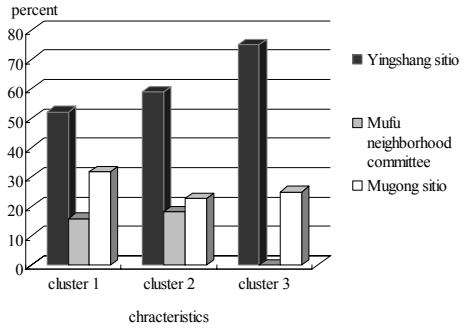

Figure 2. Distribution of the samples according to cluster groups (in percent)

The results of the cluster analysis of the survey data generate three clusters with the following descriptions:

Cluster 1 (High vulnerable - traditional farmers) - This group is mainly depended on agriculture; with poor soil fertility status; also the residences attained the lowest education; and also with the lowest income; and with the youngest members. They have no enough experience to landside. Also they are easy to affect by landside disaster. This cluster is the highest vulnerable group by the occurrence of landslide.

Cluster 2 (Medium vulnerable - large economical farmers) - This group has comparatively better soil fertility status; they not only plant more crops but also manage some other business and services. They have comparatively higher education and earn more than the cluster 1, while less than cluster 3. The age of this group is comparatively higher than cluster 1. They had experienced some landside before and known some measures to adopt disaster. This cluster is the medium vulnerable group by the occurrence of landslide.

Cluster 3 (Low vulnerable - commercial and less-farm) – They have the highest educational attainment; with the highest income; they plant less farms which is only enough for their food. They mainly depended on managing other business and services to earn money. They are not easy to affect by landside disaster. They had experienced much more landside before and known what to do in case of disaster happens. For having affected by landside, they turn to manage business to live. This cluster is not easy the highest vulnerable group by the occurrence of landslide.

3.3 Differential Characteristics of Enshi Autonomus Prefecture Residents using One-Way ANOVA(F-Test)

The F-ratio of ANOVA reveals further the significant differential characteristics of cluster groups. Table Ⅱ shows that the cluster groups differ significantly in Agriculture, agriculture-related, social and physical characteristics. No. of parcels, dominant farm slope, soil texture, age, education and income are the main factors for evaluate the frangibility.

TABLE II. Characteristics of Enshi Prefecture residents using ANOVA (F-Test)

Variables	ANOVA cluster		error			
	Mean square	df	Mean square	df	F	Sig. [a]
No. of parcels	40.98	2	1.10	96	37.41	.000***
Total farm size	0.62	2	0.17	96	3.68	.029**
Dominant farm slope	27.70	2	1.25	96	22.11	.000***
Soil fertility status	2.59	2	0.57	96	4.53	.013**
Soil texture	1.21	2	0.23	96	5.37	.006***
HH size	0.71	2	0.43	96	1.67	.094*
Age	5.95	2	1.13	96	5.26	.007***
Education	0.15	2	0.36	96	0.41	.068*
Income before	10.61	2	1.40	96	7.60	.001***
Income after	5.94	2	2.08	96	2.85	.063**
Available government help	1.01	2	0.22	96	4.60	.012**

a. Level of Significance: $p \leq 0.01$***, $p \leq 0.05$**, $p \leq 0.10$*

4. Conclusions AND DISCUSSION

The study dealt with the vulnerabilities and social characteristics of Enshi Autonomous Prefecture in Hubei province. Communities were clustered according to their similarities and differences in the biophysical, socio-economic characteristics, disaster experiences, and emergency preparedness and adaptation strategies and so on. Three cluster groups are generated from SPSS using the clustering K-Means method. The cluster 1 group is almost the traditional farmers. They are the highest vulnerable group by the occurrence of landslide. Cluster 2 group are composed by large economical farmers. They are the medium vulnerable group by the occurrence of landslide. The cluster 3 has the highest educational attainment and income. Also this cluster is not easy to be affected by the landslide.

According to the principle of "prevention first, combining prevention with control", the Enshi Autonomus Prefecture has taken some measures to prevent and control the landslide and flood. In this study, the socio-economic, biological and physical characteristics of residents were investigated and classified. Based on these characteristics, we can understand and assess vulnerability of communities furthermore. The government should take much more emergency measures to prepare and adaptation for the landslide and flood [6].

The study area locates at a typical subtropical monsoon climate zone, with abundant rainfall. Also for the landscape of geomorphic type is erodent structure and the soil texture is loose. The geological disasters happened more serious in this area. Our investigation also found that the trend of local landslide disasters was increasing in recent years. Firstly, human activities, which disturbed and destroyed the geological environment, such as mining coal, are increasing year by year. At the same time, global climate change, especially the precipitation intensity, led to serious landslide hazards in this area.

The human live have been seriously affected by landslide in Enshi Autonomous Prefecture in Hubei province. The local government should take some accurate and effective measures to protect people and their property.

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